J. Agromet Indonesia 21 (2) : 1 – 11, 2007

THE USE OF AGRICULTURE SYSTEM MODELING FOR CROP MANAGEMENT: CASE STUDY IN PUSAKA NEGARA

(Penggunaan Model Sistim Pertanian untuk Pengelolaan Tanaman :Studi Kasus Pusakanegara)

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ABSTRAK

Pemodelan sistim pertanian merupakan salah salat alat yang efektif untuk membantu pelaksana lapang dalam menyusun kalender tanam atau mengatur strategi pengelolaan tanaman. Penggabungan model tanaman dengan model prakiraan iklim akan sangat membantu pengambil kebijakan dan petani dalam menyusun strategi antisipasi kekeringan. Namun penggunaan model ini seringkali mengalami hambatan karena terbatasnya ketersediaan data iklim harian jangka panjang. Penelitian ini menunjukkan bahwa penggunakan pembangkit data iklim dapat memecahkan masalah tersebut. Aplikasi pendekatan ini di Pusakanegara telah dilakukan. Hasil penelitian merekimendaiskan ika kondisi SOI pada bulan April turun secara cepat atau konstan negatif (mengindikasikan El Nino), penanaman padi pada musim kemarau tidak direkomendasikan. Petani disarankan untuk mengganti tanamannya dengan tanaman selain padi yang memerlukan lebih sedikit air. Waktu penanaman paling terakhir pada tahun El Nino adalah minggu pertama bulan Mei. Jika panen padi pertama dilakukan setelah 1 Mei sangat disarankan untuk memberakan lahan.

Kata Kunci : sistim pemodelan pertanian, model pembangkit data iklim, curah hujan, jagung, kedelai, waktu tanam, fase SOI

ABSTRACT

Agriculture system modeling is an effective tool in assisting agriculture practitioners to make crop calendar and to set up crop management strategies. Integration of the toll with climate forecast modeling will provide greater help for decision makers and farmers to set up better drought coping strategies. However the adoption of this tool is constrained by limited availability of long historical daily climatic data. This study indicates that the use of climatic data generator can solve this problem. Application of this approach at Pusaka Negara was assessed. It is suggested that when April SOI phase is rapidly falling or constantly negative (indicating EL-Nino years), keeping planting rice in the dry season is not recommended. Farmers may need to change their crops to non-rice crops requiring less water. The latest planting time for these crops in the El-Nino years should be first week of May. If the harvesting of first rice crops occur after 1st week of May, it is suggested that the land should be fallowed.

Key words: Agriculture system modeling, climate data generator model, rainfall, maize, soybean, planting time, SOI Phases

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Penyerahan naskah: 12 Juli 2007
Diterima untuk diterbitkan : 9 Agustus 2007

INTRODUCTION

In principle, the yield of crops is determined by the interaction of genetic and environmental factors. Management practices such as irrigation, fertilization, cultivation, planting methods etc are needed to optimize the environmental condition. An improper combination of variety, environment and management causes the failure in achieving a high yield. Many computer modelers have tried to understand these interactions and use them as basis for building crop simulation models. If the models are able to mimic the real condition, it means the models are able to represent the interactions/interrelations of the two factors well. These models can be used to understand how a particular crop will behave if it exposed to particular environmental conditions. Thus, it can be used to assess the effect of climate variability on crop yield for a given crop management (Meinke and Boer, 2002).

Many researchers have used crop simulation models to translate day-to-day climate variability over the life of the crop into the range of potential yields likely under the forecast seasonal conditions (e.g. Meinke *et al.*, 1996; Nelson et al., 1998; Meinke and Hichman, 2000, Podesta *et al.*, 2002; Carberry *et al.*, 2002). In Indonesia, the use of crop simulation modeling to assess the likely performance of crops in a given seasonal climate prediction is being explored. A preliminary study showed that if SOI value in July is strong negative, indicating El-Nino years, there was no change that yield of soybean planted in August would be more than 1.0 t/ha or maize more than 2 t/ha (Rahadiyan *et al.*, 2002).

The use of crop simulation will require historical daily climatic data. However, the daily data is hardly available. In many cases, the available long historical climate data is only monthly rainfall data. This problem can be solved by using climatic data generator model that can generate daily data from the monthly rainfall data. This study assessed the use of the agriculture system modeling in evaluating crop planting and rotation strategies at Pusaka Negara, West Java Province, and the use of climatic data generator model for the agriculture system modeling.

MATERIAL AND MEHODS

This study was conducted at Pusaka Negara-West Java, one of a major food crop-producing region in Indonesia. The main cropping system in this region is rice-rice and mostly irrigated. The first rice crop is normally planted between October up to December (wet season planting) depending on the irrigation scheduling and the second rice crop is planted between April and June (dry season planting). However, the second rice crops planted late in the season normally expose to high drought risk, particularly in areas located at the end tail irrigation system and the dry season rainfall fall below normal which normally occur in El-Nino years. In this season the irrigation does not reach this area, thus the crops rely much on rainfall. If farmers know in advance the characteristics of dry seasonal rainfall, they may switch their second crop to non-rice which requires less water.

Considering the above condition, this study evaluated the performance of upland crops (soybean and maize) planted after rice under normal and ENSO years. There are many possibilities when soybean or maize can be be planted. The earliest time would be March. Thus, the simulation was done by delaying the planting time every one-week until end of June (the latest time of the second planting) using APSIM. APSIM stands for ***A****griculture* ***P****roduction system* ***SIM****ulator*, a simulation framework designed to simulate the production and resource consequences of agricultural systems (McCown *et al.*, 1996). To validate the model, a set of field experimental data conducted at Cikeumeuh, Bogor, West Java was used (Boer *et al.*, 1999). The model was run using daily rainfall data from Pusakanegara (Subang district, West Java Province) with length of record of about 28 years (1973 to 2000). Soil data was taken from a previous study (Boer *et al.*, 1999), while genetic parameters were obtained from Biotechnology Research Agencies, Bogor. The crop management applied in the simulation study is presented in Table 1.

Table 1. Crop managements used for the simulation study

Soybean	**Maize**
• Variety = Malabar (a short maturing cultivar) • Population Density = 41 Plants/m^2. • Row Spacing = 25 cm. • Sowing Depth = 5 cm. • No Irrigation applied • Fertilizers (two application, 50% at planting and 50 at 20 Days after Planting): • Urea = 100 kg/ha, TSP = 100 kg/ha and KCl = 75 kg/ha • Initial soil water was set full	• Variety = Hibrida_C1 (a short maturing cultivar). • Population Density = 4 Plants/m^2. • Row Spacing = 40 cm. • Sowing Depth = 5 cm. • No irrigation applied • Fertilizers (two application, 50% at planting and 50 at 20 Days after Planting): • Urea = 300 kg/ha, TSP = 100 kg/ha and KCl = 100 kg/ha • Initial soil water was set full

The indicator used to identify normal and ENSO years is SOI phases (Stone *et al.* 1996). The SOI phases are categorized into five. The SOI phases were determined based on SOI values in the current and immediately preceding month. The five SOI phases are: 'consistently negative denoted as 1', 'consistently positive denoted as 2', rapid fall denoted as 3', 'rapid rise denoted as 4' and 'consistently near zero denoted as 5'. SOI phase 1 and 3 may indicate dry month (El-Nino events), while phases 2 and 4 may indicate wet month (La-Nina events), and phase 5 indicates normal month. Assessment of crop performance was done by splitting the yield simulated data from APSIM into three groups based on the SOI phase information and then developing probability distribution of the yield under the three SOI phases.

The climate data generator model used in this study was developed by Boer et al. (2007). The model called CLIMGEN was developed based on works of Stern and Coe (1984), McCaskill (1990) and Epstein (1991).

RESULT AND DISCUSSION

Validation of Crop Simulation Model. The result of validation suggests that the APSIM is able to mimic the behavior of soybean crop in Cikeumeuh, Bogor very well (Figure 1). The observed data came from six soybean varities, Lokon, Malabar, Galunggung, Wilis, Kerinci and LB55 and four treatments (Boer *et al*, 1999). The first three varieties are short maturing cultivars, the second two varieties are medium maturing cultivars and the latest one is long maturing cultivars. The four treatments were a combination of two row spacing and two planting time.

Performance of Crops under Normal and ENSO years. The result of analysis suggests that planting soybean after April is still possible if the value of SOI phase in April was 2, 4 or 5, similarly for Maize (Figure 2 and 3). There is a 50% chance of getting soybean yield of more than 750 kg/ha or maize yield of more than 2000 kg/ha for May planting. This chance is getting bigger if soil water or other surface water can be used to irrigate the crops. Studies to quantify the minimum water requirement for the crops will be necessary since many farmers may keep planting the crops after April, in particular if one or two days heavy rain occurs during this month irrespective of rainfall occurrence in the preceding month.

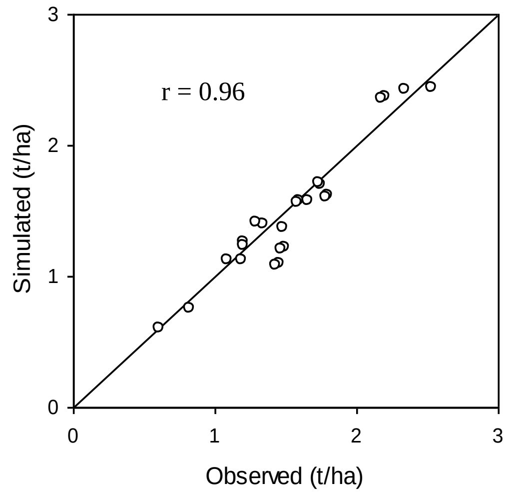

Figure 1. Relationship between simulated and observed yield of soybean

Based on crop rotation assessment, it was shown that planting third crops is not possible in Pusakanegara if there is no irrigation facility (Figure 4). The chance of having maize yield of more 2000 kg/ha planted after soybean was less than 40%. Similarly, the chance of getting soybean yield of more 1000 kg/ha planted after maize was less than 20% irrespective of climate condition either El-Nino, La-Nina or normal years.

Potential Use of Climatic Data Generator for Agriculture System Modelling. This study showed that in Pusaka Negara the CLIMGEN performed quite well in generating daily climatic data from monthly means. The variability of generated climatic data could follow the variability of observed climatic data quite well (Figure 5). This generated climatic data was used to run APSIM. The result of analysis shows that the median of simulated yield (generated using generated climatic data) have similar pattern with estimated yield (generated using observed climatic data; see Figure 6). This suggests that the use of climatic data generator model to cope with limited daily climatic data record is promoted. This also suggests that this approach can be also use to predict likely crop yields in coming season using monthly rainfall forecast.

In many cases, farmers are unable to anticipate the occurrence of long dry season. They normally keep planting rice for the second crops as water still abundance in the field after harvesting the first rice crops. But in El-Nino years, the dry season rainfall could drop and disappear quickly exposing the rice crop the drought risk. Therefore, farmers who keep planting rice in the dry season of El-Nino years always suffer from drought. Farmers should change the rice crops with non-rice crops. This study suggests that soybean and maize are the two alternative crops that can be used to replace the rice crops. These two crops can produce good yield in El-Nino years if the time of planting is done before second week of May. Thus in El-Nino years if the first rice crop is harvested after the first week of May, the land should be left fallowed as the water from rainfall will not be enough for the crops to complete their grow and development. This decision for not planting and planting in May can be made based on the April SOI phase information.

Figure 6 showed that there is a good agreement between median of simulated yields generated using daily climatic data (UGCD) from monthly means and estimated yield using observed daily climatic data (UOCD). This finding open opportunity for agriculture field managers or decision makers to use monthly rainfall forecast to predict the likely rice production for a coming season. However, the reliability of this approach will be heavily depended on the skill of the climate forecast. If the forecast skill is good, then the use of this approach is encouraged.

CONCLUSION

(1) The agriculture system modeling is an effective tool in assisting agriculture practitioners to make crop calendar and planting decision. Integration of the toll with climate forecast modeling will provide greater help for decision makers and farmers to set up better drought coping strategies.

(2) In El-Nino years, keeping planting rice in the dry season may expose the crop to higher drought risk, therefore changing the rice crop with non-rice crops requiring less water is recommended.

(3) Soybean and maize are two alternative crops to replace rice crop in dry season planting of El-Nino years. The latest time for planting these crops is the first week of May. If the harvesting of the first rice crop occurs after 1^{st} week of May, the land should be left fallow.

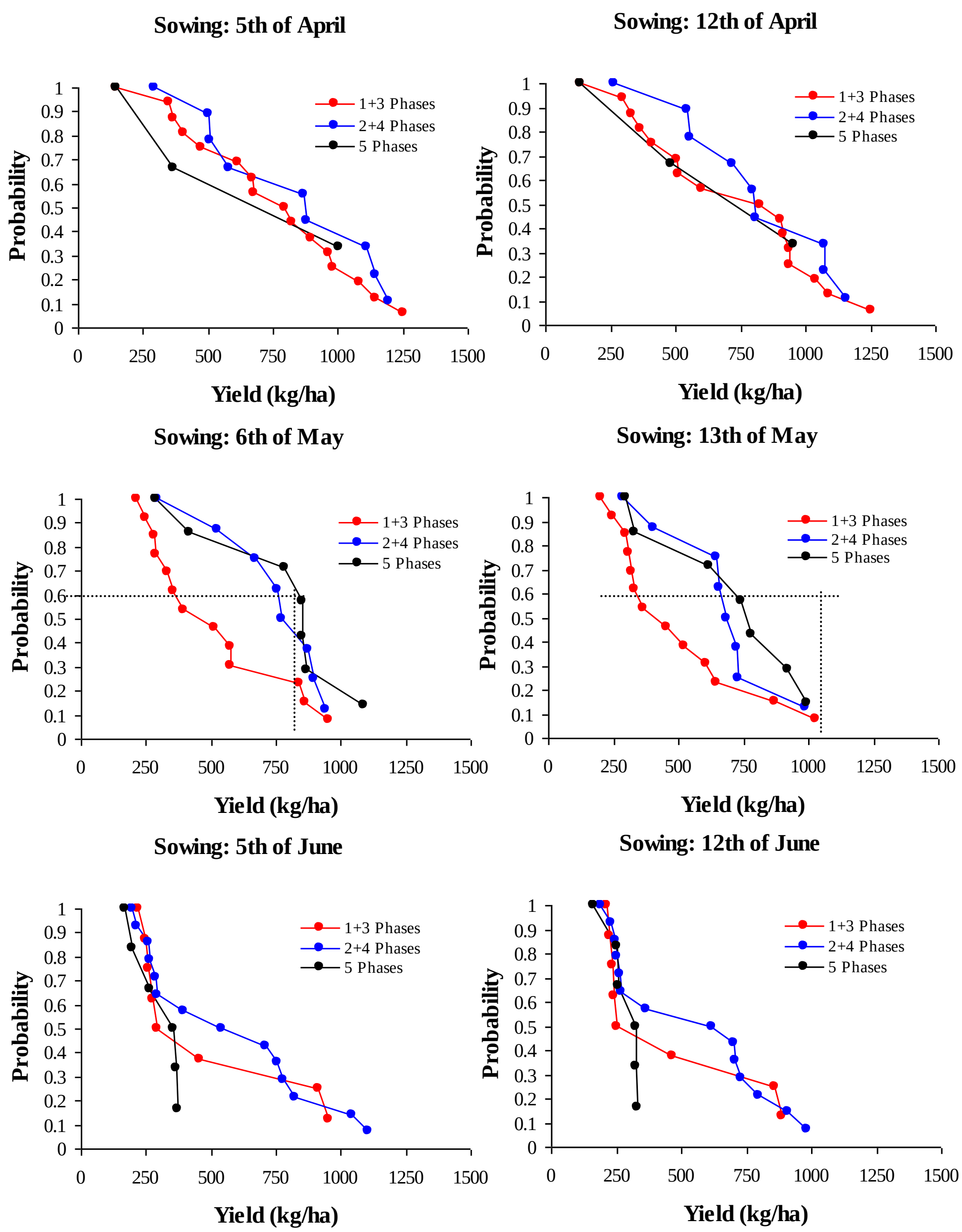

Figure 2. Probability of soybean yield at different sowing times based on previous month SOI phase

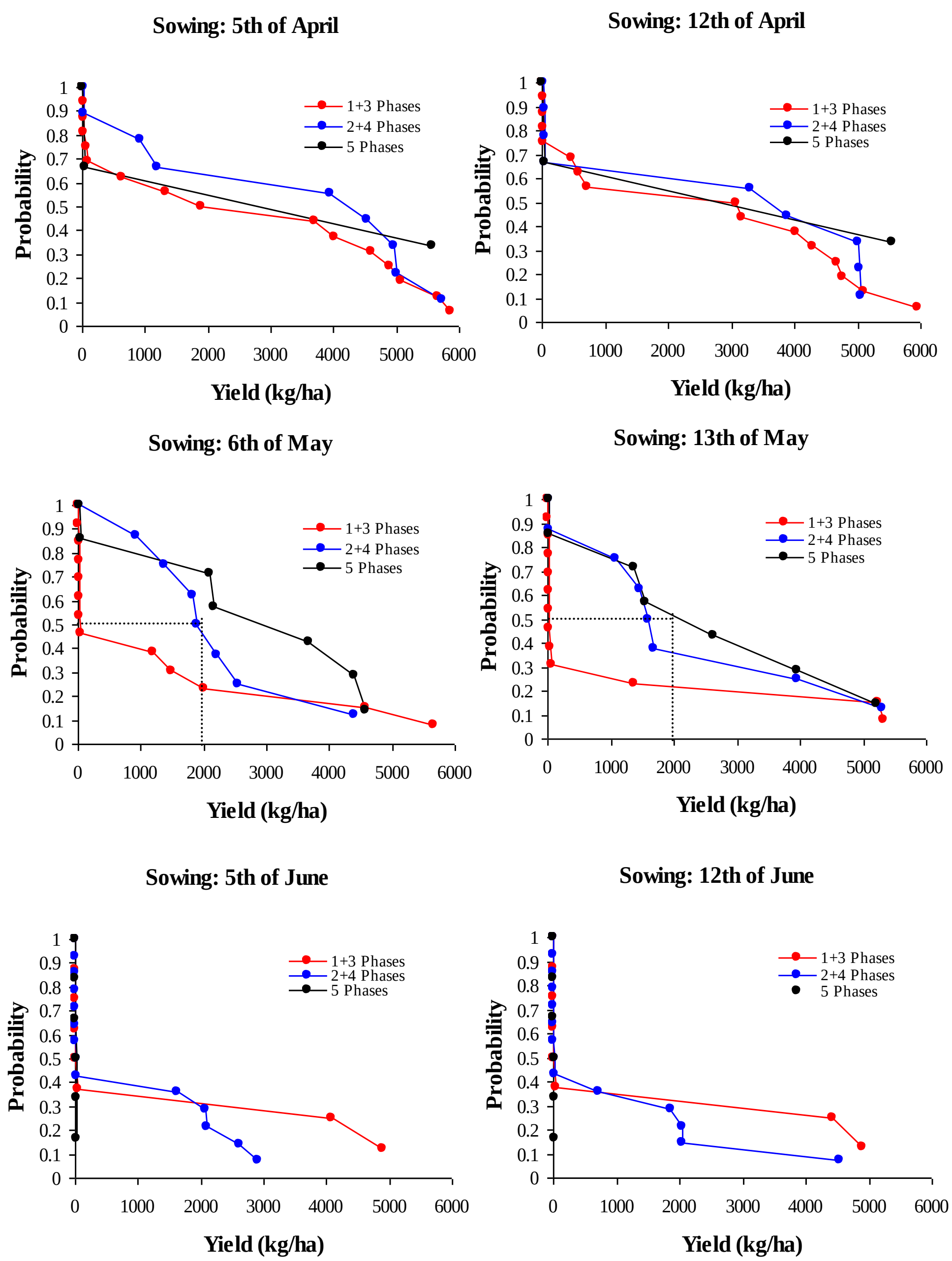

Figure 3. Probability of maize yield at different sowing times based on previous month SOI phase

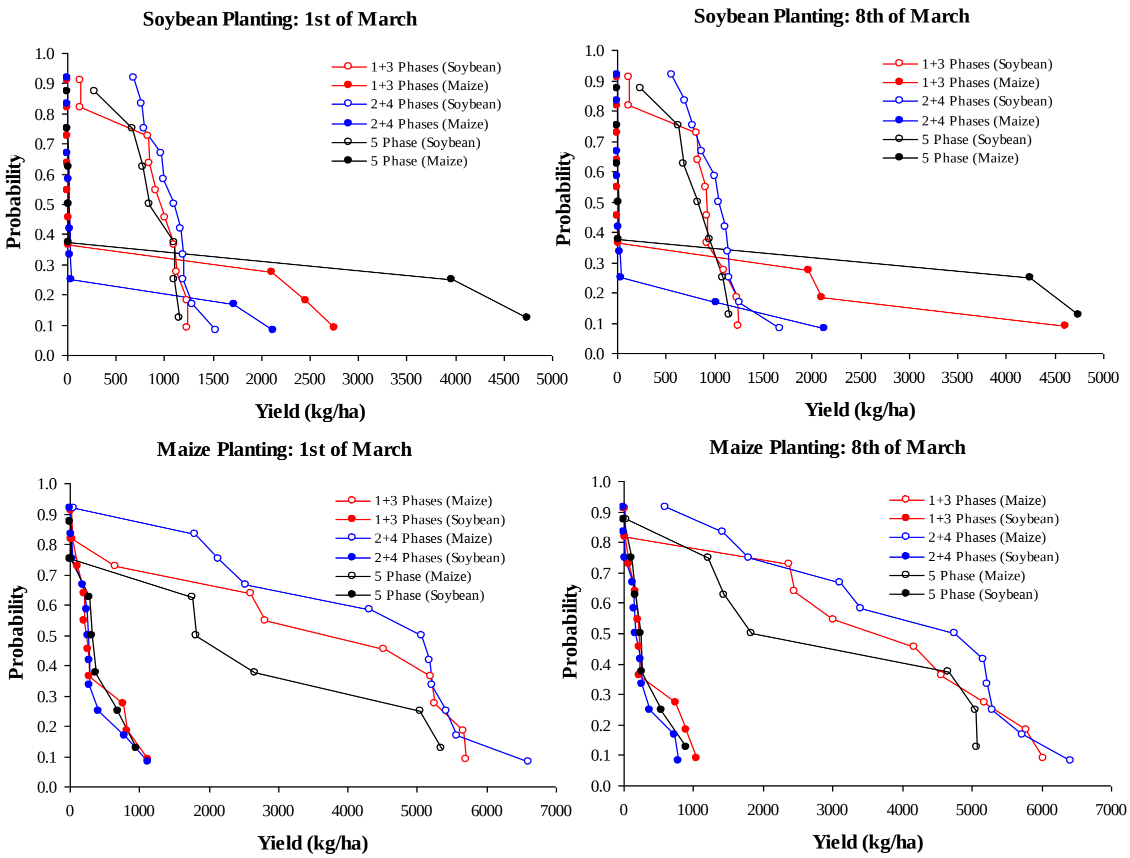

Figure 4. Probability of Maize and soybean yields at two different sowing times and two rotation systems soybean-maize (top) and maize-soybean (bottom) based on previous month SOI phase

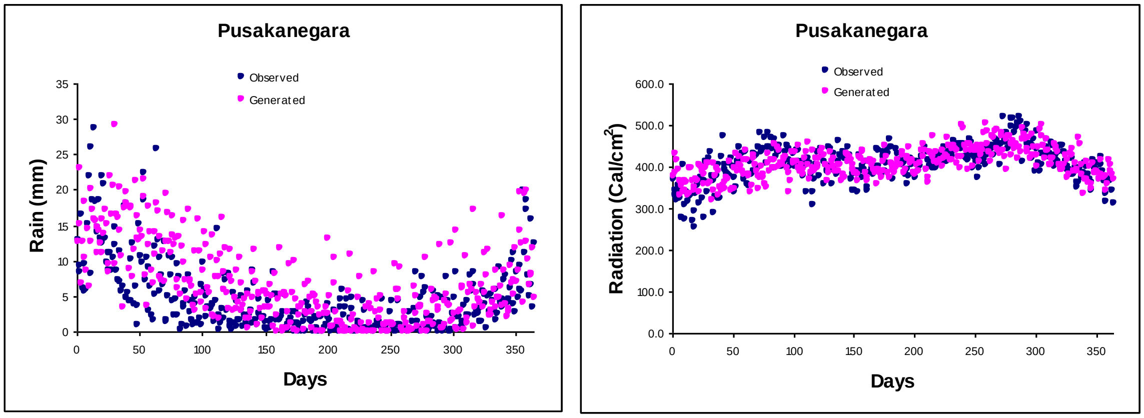

Figure 5. Comparison between estimated yield (estimated using observed climatic data) and median of simulated yields (simulated using generated daily climatic data) at Pusakanegara.

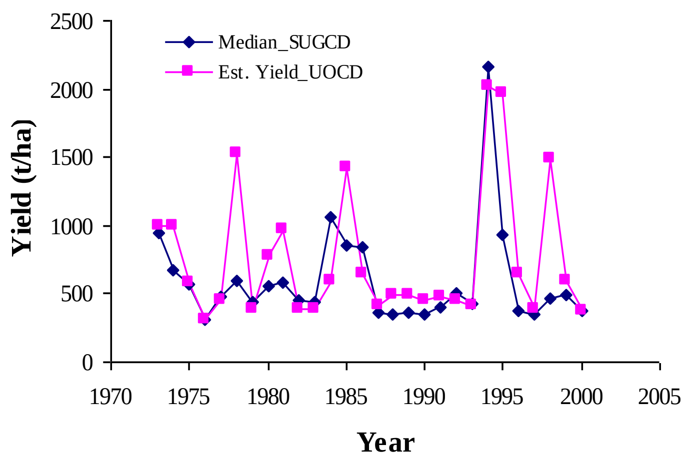

Figure 6. Comparison between median of simulated yields generated using daily climatic data (UGCD) from monthly means and estimated yield using observed daily climatic data (UOCD)

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